REMARKS

Restriction Requirement

Applicants note that the restriction requirement has been made final, and acquiesce to the withdrawal or cancellation without prejudice of all pending claims except 68, 69, 71-73, and 76 (i.e. claims 1-7, 28-44, 70, 74, 75, and 77).

Information Disclosure Statement

Such will be submitted as requested.

Specification

Applicants note the objections to the specification (Office Action at paras. 6-8) and respond via the following remarks.

We, the inventor's, acknowledge the examiner's position regarding description and enablement in the specification; however, the specification was drafted with the intent to describe and enable the invention and we believe that the specification describes and enables one skilled in the art to be able to construct and operate the innovation claimed. With regard to a specific operative embodiment of the invention (vessel, electrodes, etc) required for one of ordinary skill in the art to make and/or use the invention, we believe that the specification does provide enough information for one of ordinary skill in the art to make and/or use the invention. Much of the specification is devoted to teaching those things which may not be commonly known to those skilled in the art, for instance the operating conditions and characteristics of a fast-neutral and ion dominated discharge, where electrons play a diminished role compared to ordinary gaseous discharges. This is discussed at length throughout the specification. These descriptions of physical processes are tied in with the design of the invention by stating how electrode geometries and material properties (which those skilled in the art would be familiar with) affect the discharge. This is then brought into physical form by a description of the actual prototypes that we built, which contain materials, relevant dimensions and the interconnection between parts.

Given this information taught by the specification, the specification provides design data from our reduction-to-practice prototype units that enable one of ordinary skill in the art to recreate the invention, by directly copying it if necessary. In paragraphs 167-169, the dimensions of the chamber, how it is put together, how vacuum is achieved and electrical connections are given, namely, a 27-cm diameter 1-m tube vacuum chamber pumped with an oil diffusion pump and rotary vane roughing pump. The pressure is controlled by regulating the gas feed rate (any reasonable means of doing this will work; the important information is that pressure must be controlable/setable, several means of doing this are known) and is monitored with a thermocouple gauge. Additional information, such as how the vacuum seals are achieved (o-rings) and safety precautions, are also given in the specification. The vessel material, stainless steel, is mentioned several times in the specification (such as paragraph 172). The specific type of stainless steel is not mentioned because common types, such as 302, 304 and 316, all have similar characteristics from the point of view of plasma interaction (i.e. secondary electron emission), and any of them would work and be approximately equivalent.

The electrode material is similarly described in paragraph 170. The single-cathode device is 91-cm in length and is made from stainless steel hardware cloth wrapped into a 5-cm radius with steel end caps. This information, coupled with the photograph in Figure 14 should allow anyone of ordinary skill in the art to reproduce the described invention.

The additional innovations that follow the single-cathode reduction-to-practice prototype build on this information: the same vacuum chamber, feedthroughs, pump units, gas control and pressure monitoring units are used for each reduced-to-practice innovation. The cathode materials, such as hardware cloth, are referred to in these innovation descriptions, in addition to other materials that were used to make the other cathode designs. Building upon each innovation seemed an effective way of teaching how to build and practice the invention, which is one of the goals of the patent.

In the case of a leeching electrode with a suppressor electrode, the materials, their dimensions and how they are put together are given in the specification in paragraphs 190 and 191 and

Figures 27, 13, 24 and 29. In paragraph 209, the description of the sheet-metal suppressor electrode referred to in paragraphs 190 and 191, which is also a repressing electrode, is further refined: it is made from 0.005-inch thick stainless steel shim stock with 1-cm diameter holes spaced 5-cm apart. It should also be noted that the materials used for building the reduction to practice device, such as "hardware cloth" and stainless steel pipe, are all common off-the-shelf materials whose properties are well known to anyone skilled in the art.

This information, coupled with Figures 27-40 allows the construction of ANY of the innovations by anyone with ordinary skill in the art.

Response Section

On Page 4, Section 8 and on Page 6, Section 10 of the action office action dated Oct 27, 2003.

The action objects to the specification and claims as failing to provide an adequate written description of the invention, as failing to adequately teach how to make and/or use the invention (i.e. failing to provide an enabling disclosure).

The action specifically cites no enabling disclosure of specific operative embodiments of the invention, including vessel, electrodes, etc. required for one of ordinary skill in the art to make of use the invention. The action states that some parameters are set forth, but an operative embodiment with specific values for each of the parameters is not recited, specifically materials used, applied current and voltage, assembly of the apparatus, vacuum chamber and shielding, calibration of the instrument during and after experiment, degree of purity and impurities present, temperatures, time operated, etc.

The inventors respectfully disagree. The specification goes to great lengths to teach the method of the invention, laborate on construction and assembly techniques, and cites specific operational testing param ters used in the reduction to practice of the innovation.

The inventors have identified the critical aspects of the innovation, specifically the high-pressure, high-resistance discharge mode, its application to gas-target neutron production, and mechanisms to optimize and increase the specific neutron yield (neutrons per watt).

The action makes reference to a lack of specific device calibration in the specification. On page 55, Section 171 states that the proof-of-principle machine was calibrated with a paraffin-moderated helium-3 neutron detector. One skilled in the art with experience in neutron detectors would know that detectors are calibrated with a reference known neutron source, resulting in a counts-to-flux conversion factor. This conversion factor is usually provided by the manufacturer or obtained at another research facility. Since the inventor's did not have a calibrated neutron source, such as a Pu-Be radioisotope decay source, an in-situ calibration was not possible. Thus, the reference calibration against a radioisotope source obtained less than 1 month prior to testing was used. However, the specifics of this calibration were not included in the specification and deemed known to one of ordinary skill in the art.

The action makes reference to a lack of quantifiable data (current and voltages) on the operational data for the device under testing. Page 56, Section 171 also cites actual neutron production data from deuterium fusion reactions of 2 x 10^6 DD neutrons/second for a –45kV 22mA operation. Figure 16 shows the per-unit power scaling and extrapolation to higher voltages and higher powers (not tested due to limitations in experimental setup and safety). However, the case is made that to one of ordinary skill in the art of nuclear fusion and particle beams, the scaling of reaction rate with fusion cross-sectional probability is straightforward. Additionally, Figure 16 shows the projected benefits from implementing the electron management techniques and device optimization. Again, this teaches one of ordinary skill in the art the enabling technology to improve neutron generator specific power performance.

The action references a lack of shielding information. To one of ordinary skill in the art of nuclear radiation producing devices will know the attenuation coefficients for x-ray br msstrahlung radiation escaping the vacuum vessel (another reason for decreasing electron

processes) and neutron radiation. The thickness of the device to attenuate and stop radiation is an engineering decision based on local regulations for allowable exposure limits, and is something to be calculated and engineered at the time of design and manufacture. Ultimately, the decision to use separate shielding materials (not part of the invention) or to use the vacuum vessel materials for shielding is dependent upon economic and engineering issues, such as required mechanical strength of the vacuum chamber balanced with fabrication costs of a heavy walled vessel compared to external shielding costs.

The action references a lack of information on degree of purity and impurities present. This is a very open ended question, since it would be impossible to know the exact values of all elements, chemical compositions, bonding angles, crystal lattice orientations, material finish. Impurities present in the gas will impact the reaction rate equation proportionally to the impurity presence. So if the target gas was only 50% deuterium, then roughly 50% of the collisions will not contribute to fusion neutron production. Thus, to one of ordinary skill in the art, the impurity question is straightforward and does not require specific evaluation in the specification.

The action refers to the specific section in the specification where material selection for minimizing the secondary electron production is discussed; again it is an engineering cost issue vs. the degree of improvement gained. The inventor's goal of the specification is to teach that electron effects are to be minimized to improve performance and operation of the gas-target neutron source in a high-resistance, high-pressure mode. One of ordinary skill in the art would be able to select a decreased secondary electron material from available engineering database for use in constructing the device to improve performance with engineering cost vs. performance to be made at the designer level.

The action makes direct reference to lack of information on the time operated for the reduction-to-practice of the device. This information was not deemed necessary, since relevant parameters were given for each section and to one of ordinary skill in the art, the replenishable gas-target has a near infinite lifetime. The inventor's believe such lifetime testing appropriate for a full commercially engineered system.

The action states that the specification and the claims are non-enabling, non-teaching, and non-specific with respect to parameters. The following pages cite specific pages/sections in the specification as a rebuttal with explanation.

Page 3, Section 8

The specification enumerates the device relates to fusion neutron production. To overcome the coulomb forces present in the nucleus, to attain fusion reactions, high energies are required in excess of 10 keV. The values for the fusion cross-sectional probabilities for interaction are well documented and published in graduate textbooks and the NRL plasma formulary or the barn book. One of ordinary skill in the art would know the energy (voltage) scaling laws for sigma-v for Maxwellian and sigma-v for beam fusion. Thus, specific energies (voltages) applied to deuterium will result in specific potential fusion yield through a reaction rate equation RR = n1 n2 sigma-v V.

Page 5, Section 13

The specification specifically states that a major component in the innovation lies in proper electron management to increase device efficiency. There are several fusion neutron devices cited in the literature, involving solid, gas and radioactive targets. The present innovation utilizes a replenishable gas target, but to overcome the inherent inefficiencies in the system, careful electron management is needed.

Page 6, Section 16

The innovation is titled a high-pressure, high-resistance gaseous discharge neutron generator. For one normally skilled in the art, to maximize the reaction rate equation to yield the highest number of fusion reactions, the densities n1, n2, sigma, v and V (up to the energy corresponding to the maximum of the fusion reaction cross section of interest) need to be increased. Since n1 represents the injected ion current, then increasing this value results in

higher input power.. Increasing n2 represents increasing the number of gaseous targets in the device. Likewise, increasing the volume (V) of the device increases the average distance over which fusible particles can travel at high energy, resulting in increased neutron yield. The product n2V represents the number of "target" atoms in the volume. The cross sectional probability, sigma, and the velocity (v) are dependent on the energy of the fast particles. However there are competing effects in the discharge that will limit the reactions.

The term high-pressure enables an increase in n2 gas target density and Volume, increasing the number of potential interactions. The term high-resistance enables the operation of the device at high-energies, while mitigating negative discharge effects that would limit device operation and efficiency at these energies. The inventors describe and teach to one of ordinary skill in the art a series of substantive steps to force a high-pressure high-resistance gaseous discharge and its optimization for improving fusion reaction rate and neutron yield.

Page 6, Section 17

The present innovation departs greatly from previous nuclear fusion attempts since there is no plasma confinement. Nearly all fusion concepts involve trapping ions at high energies within electrostatic and electromagnetic fields. The action makes reference to other fusion concepts that employ gas-targets, such as Hirsch and Miley, which utilize electrostatic confinement mechanisms and the establishment of virtual electric wells with deep potentials to achieve the requisite fusion reactions. In these inertial electrostatic confinement (IEC) concepts, the trapping mechanism is sustained by trapping high-energy ions and high-energy electrons in a recirculating medium. The present innovation seeks to eliminate any trapping mechanism entirely.

The present specification states that the transparent electrodes are not meant to confine fast atomic particles (ion and fast-neutral deuterium). The use of semi-transparent electrode grids is not uncommon to one of ordinary skill in the art of plasmas and particle accelerators as a means of imparting energy to ions and electrons. Indeed, the specification goes to great

lengths to illustrate that a variety of electrode configurations can be used (planar, cylindrical, etc.) to impart momentum to deuterium ions.

To argue the case further, the present innovation goes to the opposite extreme; the destruction of any potential wells or virtual electrode trapping mechanisms, leading to no atomic particle confinement. The baffle electrode surfaces present within the hollow cathode interior (that are a local sink for electrons) indeed disrupt any electrical potential surface as dictated by Miley and Hirsch. A requirement for inertial electrostatic confinement is the formation of multiple virtual electrode surfaces, necessitating the presence of electron space charge (excess electrons). The present innovation reduces and eliminates the virtual electrode surface and the presence of electron space charge (excess electrons). The direct result of the innovation is a high-energy discharge accelerator that operates without significant electron transport mechanisms, and is fast-ion and fast-neutral deuterium dominated. The inventors believe that the specification teaches one of ordinary skill in the art the rationale and methodology for achieving this with specific, concrete embodiments.

The elimination of virtual electrodes formed via space charge is not a trivial extension of the work of Hirsch and Miley. In the fusion-power community in general, charge-exchange processes and the resulting fast neutrals are considered a large energy loss; this is especially true in inertial electrostatic confinement schemes, such as Hirsch and Miley because neutrals cannot be influence by electric (or magnetic for that matter) fields, and the confinement volume of these IEC systems is very small. The small confinement region in IEC devices makes charge exchange a particularly damaging loss term. The large volumes contemplated for magnetic confinement schemes make this loss term somewhat more tolerable, but it is still highly undesirable. In the case of the HPHRGD, fusion power is not the goal – a long-lived neutron source with a comparatively small geometry and low input power is the goal. The HPHRGD device cannot and will never be a fusion-power concept – it is a neutron source. For a given HPHRGD source design, the neutron output will generally scale linearly with input current (input power). This does not allow breakeven. However, if the design of the neutron source is improved, the slope of this linear current dependence can be increased. Fusion power is still not possible, but such a unit can still produce more neutrons than a

fusion-power reactor concept at low power levels and small sizes. Bear in mind that the term "low power level" in this case is relative to fusion power reactor inputs, which are greater than 1 MW, and "small size" is also relative to fusion power reactor inputs, which usually fill a room, if not a large building, compared to a HPHRGD, which may only occupy a tabletop.

In simplified terms, the HPGRGD system does not put power into forming and sustaining a confinement system. The design and operation of the present innovation seeks to raise baseline fusion neutron per unit power baseline level at which to apply linear scaling of neutron output with input power. The present innovation yields significantly higher neutrons per kilowatt input power, as noted in the specification for the incorporation of electron management and the high-pressure, high-resistance mode of discharge operation.

Fusion power concepts rely on better-than-linear scaling of fusion rate (directly proportional to neutron production) with input power (better-than-linear scaling with current for a given IEC voltage). Because fusion power concepts rely on "economies of scale", efficient neutron production (fusion) does not occur until input power levels are quite high – often on the order of megawatts to hundreds of megawatts. For this reason, a device, such as the HPHRGD, which can never reach "breakeven" conditions can out-perform fusion-power concepts, such as IEC, at comparatively lower power levels/device sizes because fusion-power concepts are inefficient until very high power levels and device sizes are achieved.

It is noteworthy that Hirsch and Miley also used small-scale devices; however, their goal was the same – demonstrating confinement. To achieve confinement, especially on such small scales, required a very high input power (per unit neutron generation) because the power producing region, in which better-than-linear scaling of fusion rate (neutron production) with input power exists (the "core" region where ion-ion collision dominate), is very small compared the rest of the device that is required to sustain such a confinement scheme. In other words, in order to sustain the fusion reactions in the small point-like volume in an IEC configuration, power is distributed over the large chamber volume to generated the plasma confinement scheme to enable large fusion reaction scaling.

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Page 7, Section 19-21

The present innovation describes a series of successive methods to maximize the reaction rate equation for a given device geometry, through increasing gas pressure (n_2) and target density (volume), suppressing electron effects, forcing a high-resistance discharge that is driven and sustained through ion and fast-particle collisions that minimizes energy losses due to electrons. The present innovation is a neutron generator that offers high neutron output per kilowatt input, compared to existing neutron generators, including those that employ gas or plasma targets (Hirsch and Miley).

Page 12, Section 32

The specification states that to attain the high-pressure, high-resistance gaseous discharge, the electrons must not contribute significantly to the global discharge process, i.e. no formation of virtual electrode, no significant current carrying capability, no influence on the discharge, etc.

In gaseous systems such as Miley, the formation of electron virtual electrodes requires a substantial amount of power and inefficiency, since these electrons ultimately contribute to discharge current. To increase the fusion yield in these systems, a higher amount of electron current must be driven to due to the spherical symmetry required for ion trapping. Since the virtual electrode trapping volume is so small, to increase the volume, an even greater amount of electron current must be driven in the system to sustain this large volume. There is a law of decreasing returns, since the trapped volume $4\pi r^3$ is much smaller than space charge required to form the confinement structure $4\pi R^3$ (where $R >> r$). To scale these systems to higher fusion yield, electrons must carry a greater amount of discharge current; this decreases efficiency per unit power input.

Nearly all gaseous discharges are electron dominated, where electrons carry a majority of the discharge current >90%; this includes the references cited by the action of Miley and Hirsch. The present innovation takes an exactly opposite approach, instead of confining particles and

trying to achieve plasma confinement, the present technology is a brute force optimization for power efficiency by limiting electron effects. Each fraction of discharge current not carried by ions is wasted power, since only the acceleration of deuterium ions to high energies will result in fusion neutron yield. Thus, improving the ion discharge fraction is critical to engineering an economically viable portable neutron generator. The present innovation accomplishes this through electron management and optimization of the device geometry based on set of parameters. The high-resistance, high-pressure label for the present innovation is an enabling description of the invention.

The action makes specific reference that there is a parameter space given, but no specific discrete dimension for the optimal system. This is correct, since any given geometry (planar, parallelepiped, etc.) can be adjusted for optimization depending on the voltage, thermal current loading capability, and specific engineering situation. If an application requires a 10-meter long device for the irradiation of a mineral ore channel, then a high-pressure, high-resistance gaseous discharge neutron generator device could be engineered to operate under this dimension utilizing the specific teachings as described in the specification. However the choice of dimensions will greatly depend on the economics of the power supply used, material availability, etc. For example, a 50kV power supply or a 100kV power supply could be used, depending on the cost of the components from available suppliers. To one of ordinary skill in the art, operation of the device closer to the peak of the fusion cross-section curve will result in greater fusion yield; however, the decision would be made at the time of construction and implementation.

The inventors have described the innovation, such that one of ordinary skill in the art could understand what is claimed and could construct and operate a device according to the invention.

Page 16, Section 42-46

The sections of the specification outline in detail what is termed "electron suppression", electron "repression", inter-electrode baffling, material selection to inhibit electron formation, and optimization of the electrode gap spacing, encompassing what is termed as electron management. These effects, in whole or in part, will improve the neutron specific power (neutrons per watt).

Page 35, Sections 119-122

The specifications elaborate further on items outlined above, teaching how and why to design and configure the high-pressure, high-resistance gaseous discharge neutron generator. This is an enabling disclosure on the method for obtaining the desired effect.

Page 38, Section 127

The paragraph explains the role of Pashcen breakdown and sustainment in discharge device design and fabrication. One of ordinary skill in the art would recognize the basic principles behind gaseous discharge mechanics and understand the relationships for discharge breakdown and current sustainment. In the present innovation, this is taken a step further for deuterium fast ion and neutral particle contribution towards discharge sustainment. This section is specifically enabling and teaches something not commonly available in the literature, since nearly all discharges are operated in low-resistance electron-dominated mode.

Page 40, Section 130

The specification states a voltage parameter range for operation of the device. A value of 10s to 100s of kV is given. As stated earlier, the selection of an appropriate voltage will follow the sigma-v for a given deuterium energy for nuclear fusion probability, however, the appropriate selection in operating voltage will be made on economic reasons.

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Page 45, Section 144

One of ordinary skill in the art would know that there is a peak in the impact ionization cross-sectional probability for generating ionizing collisions to sustain a discharge. While the peak of the fusion cross section is >200 keV for deuterium, the sweet spot for high-resistance discharge operation occurs at about 70 keV. At this energy, the bulk fast particles, deuterium ions and charge-exchanged fast neutral deuterium, can drive the discharge.

Page 55, Section 169-171

The action states that the specification lacks quantifiable and discrete values for the reduction to practice device shown in the figures. These paragraphs give an operational length for the vacuum chamber of 1 meter, a diameter of 27 cm, material composition of stainless steel vessel, single electrode configuration of stainless steel hardware cloth (commonly available at a local hardware store or industrial supply company such as McMaster-Carr), construction of the cylindrical electrode using 5-cm diameter stainless steel plates, an operating voltage of –45kV, and currents of 22mA.

Page 57, Section 175-179

This section of the specification teaches in elaborate detail the construction and operation of the leeching-suppressor double cathode grid combination for electron management. The suppressor electrode effectively shields the anode-cathode space from electrons generated within the cathode volume. Instead of these electrons traveling to the anode and drawing non-fusion-generating current, the electrons are extracted and absorbed from the cathode region by the leeching electrode. In fact, the electrode is named for this reason; the electrons are sucked out of the cathode region before they can contribute negatively to system current (as if a leech removed the bad blood).

These sections show to one skilled in the art the physical mechanism and design to mate with the concept of electron removal elucidated earlier in the specification. Therefore, it teaches one skilled in the art how to apply these concepts.

Page 62, Section 190-191

Likewise, the reduction to practice section for the double cathode electrode leech-suppressor configuration is shown. Local dimensions for the electrodes employed are given in this configuration of 13-cm and 15-cm diameter for the leech and suppressor. What is not shown, but obviously assumed, is that the vacuum chamber dimensions and materials remained constant, 1-meter length, 27-cm diameter, stainless steel vessel, etc.

Page 65, Section 198-199

These sections explain the impact of electrode surface geometry, penetration of the vacuum field, and the limitations on internal vacuum field. Since electrons generated within the cathode volume will gain a fraction of this field energy, repressing (limiting) this electron energy loss is important to increase device specific power efficiency (neutrons/watt). A detailed simulation showing the effects of electrode geometry and impact on vacuum potential is given.

However, as the number of discharge channels is reduced, the amount of current carried in each channel increases and leads to thermal limitations on the discharge vessel. Also there is some scattering in the fast ion and neutral particle plasma channel, leading to potential losses from ion impacts. This section teaches on skilled in the art the ability to shape the internal electric potentials within the cathode volume to minimize energy losses.

Page 69, Section 209

Local dimensions are given for the repression-style electrode, 0.005-inch thickness stainless steel. Again the other system parameters are given in the previous sections.

Page 70, Section 212-214

The specification further describes the baffling component to the electron management system by providing physical barriers to electron and errant deuterium particles. The baffling concept can be used in conjunction with the leech-suppressor electrode arrangement for additional electron removal and high-pressure high-resistance operation.

In addition to the other device parameters and engineering discussed, the baffling techniques present physical barriers to the establishment of potential formation, further separating the present innovation from that of Hirsch and Miley. The goal is to have ions accelerated to high energies impact with gaseous targets without deleterious electron effects (low-resistance, power loss, and confinement). The inventors go to great lengths in the specification to teach how to obtain and develop the high-pressure, high-resistance gaseous discharge towards this end.

Page 73, Section 222-223

The specification outlines the reduction to practice of the baffles within the previous single electrode configuration referenced earlier. The diameter is previously cited at 5 cm. The baffle materials are stainless steel, as employed throughout the reduction to practice.

Page 74, Section 227

This section teaches the effects of surface properties on the device performance. One skilled in the art of plasma-material interactions would know the secondary electron emission and field emission effects and data sets that are commonly available from NIST and Oak Ridge National Laboratory.

Page 76, Section 234

The reduction to practice section states that stainless steel materials performed better than the aluminum, galvanized steel and plain steel components tested on the proof-of-principle device. Thus, and actual embodiment is given again teaching and illustrating specific parameters relevant to one skilled in the art.

It is thus respectfully requested that the specification be favorably reconsidered and the objections thereto be withdrawn, and that the claims be favorably reconsidered and the rejections thereof be withdrawn.

Insufficient Antecedent Basis

The action states that "Claims 68, 69, 71-73 and 76 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention," because "the claims appear to be replete with insufficient antecedent basis." The inventors acknowledge the action's objections and have amended the claims to clarify the concept.

It is thus respectfully requested that the claims be favorably reconsidered and the rejections thereof be withdrawn.

Claim Rejections

As discussed in the previous sections, the inventors believe that the best mode of the innovation contemplated by the inventors is disclosed adequately to allow one skilled in the art to reproduce the invention. The inventors also recognize that the disclosed innovation seems similar to the prior-art inventions of Hirsch and Miley; however, the innovations are different in the specifics of their construction and operation. The action states that

> Hirsch (see entire document) sets forth a system for producing nuclear fusion reactions inherently capable of meeting applicant's claimed inventive concept. Particularly, Hirsch sets forth a process wherein voltage differentials between semi-transparent cathode electrodes (20 and 22) and the anode electrode (21) are applied to fusion reaction gas (deuterium) environment. Note that since the voltage differential exists between the semi-transparent cathodes and anode utilizing a deuterium gas in a vacuum

> environment the claimed high-pressure high-resistance gaseous environment or electron cloud further includes a neutral gas (background gas) which interacts with the electrons and deuterium gas to produce the claimed nuclear fusion reactions. While Hirsch is silent on the production of fast-neutral particles (neutrons) Hirsch utilizes the same materials as applicant therefore Hirsch must inherently produce neutrons.

Each of the action's points will be discussed individually; however, there is one point that is essential to understanding the disclosed innovation and must be clarified. The action states: "While Hirsch is silent on the production of fast-neutral particles (neutrons) Hirsch utilizes the same materials as applicant therefore Hirsch must inherently produce neutrons." The important clarification is that "fast neutrals" and "neutrons" are not the same thing. Fast neutrals are neutral atoms that result from charge exchange collisions of high-energy ions with neutral background gas (an atomic interaction). Neutrons are subatomic particles released during the fusion of deuterium with deuterium (a nuclear interaction). Hirsch, Miley and the present innovation are all designed to produce neutrons via fusion. However, in the case of Hirsch and Miley, charge exchange reactions are not stressed as part of the innovation because they are considered as an energy loss to the system, and in their systems they are a loss because they decrease confinement. In the present innovation, the charge exchange process is used to increase fusion rate – the HPHRGD neutron generator and its subinnovations are specifically designed to increase background gas pressure while maintaining a high operating voltage (hence the name: high-pressure high resistance gaseous discharge) which promotes fast-neutral production at high ion energies. Both Hirsch and Miley seek to minimize the background gas pressure in their devices because they want to increase the rate at which ions interact with other ions relative to the background neutral gas and because they seek to confine energetic ions via space charge fields ("electron clouds"). Neither Hirsch nor Miley contemplated the discharge mechanisms, characteristics or mode of operation of a HPHRGD neutron source. This is evidenced by the action's own statement: "... Hirsch is silent on the production of fast-neutral particles..." Claim 68 explicitly refers to the intentional generation of fast-neutral particles to undergo fusion with the background gas, hence, Claim 68, 69, 71-73 and 76 (and all other claims relating to the disclosed invention) do not read on those of Hirsch and Mil y.

As stated in Miley's patent in Column 3:

> The glow discharge generates ions which are extracted from the discharge by the electric field created by the cathode grid. These ions are accelerated through the grid openings and focused at a spot in the center of the spherical device. The resulting high energy ions interact with the background gas (beam-background reactions) and themselves (beam-beam collisions) in a small volume around the center spot, resulting in a high rate of fusion reactions. The result is a neutron generator producing neutrons as one of the D-T fusion reaction products. Where the ejection rates are high, the ejected ions may provide a deep-self generated potential well that confines trapped beam ions, creating even higher reaction rates.

Several essential characteristics of Miley's neutron source are apparent from this quotation: (1) it requires focusing of ions to a small spot, (2) Ion fusion interactions with other ions and the background gas are the dominant/exclusive means of generating neutrons and (3) the ions form a self-generated potential well to confine ions (a space-charge potential that confines ions). The HPHRGD invention intentionally does NOT focus ions because this would create a space charge potential structure (a virtual anode and, as Miley claims, possibly a virtual cathode) which results in lower operating pressure for reasons described in the HPHRGD technical specification. Furthermore, Miley does not contemplate fast-neutral generation and the use of fast neutrals to sustain the discharge and generate fusion neutrons. The reason that this is not contemplated by Miley is that high fast-neutral generation rates destroy confinement (neutrals cannot be confined by electric or magnetic fields) and are detrimental to his neutron generation efficiency because he is using ion confinement to achieve fusion rates. The intentional exploitation of fast-neutrals for fusion neutron generation in the HPHRGD is not simply a modified version of Miley's neutron generator – the HPHRGD uses an entirely different set of physical principles. The HPHRGD is a gas-target neutron source, in a manner such that there is no confinement, focusing/space charge or intentional ion-ion interactions.

The specific intent of the innovation discussed here is to pevent the formation of space-charge potentials because space charge potentials decrease the background gas pressure required to sustain the discharge. This key difference is reflected in th difference between

Hirsch and the present innovations use of an electron management system. While Hirsh and the present innovation both use an electron management system, as many electronics devices do, their purpose – what they do to the electron population – is entirely different. Hirsch seeks to generate, confine, focus and accelerate electrons in a central region to create a virtual cathode that confines and focuses high-energy ions in a low background-gas pressure environment. In the case of Hirsch, the goal of focusing ions and electrons to achieve confining space charge potentials (in many cases, with voltages in the 10s-100s of kilovolts!) and the goal of minimizing the background gas density (minimizing the operating pressure) are illustrated in the following excerpts from Hirsch's patent:

In Column 2

> The ion-production device includes a drift chamber, a vacuum pump being connected to the drift chamber for scavenging neutral gas therefrom. Electrode means including the anode and cathode are provided for focusing the ionized particles from the drift chamber into the anode toward the center of the cathodic volume, it being the objective that the focused ions follow essentially radial paths whereby a maximum number of ions will reach the center where the fusion probability is highest.

In Columns 3 and 4

> An electrical discharge composed of high-magnitude electron and ion currents forms in the volume inside the cathode and develops a difference of potential which is adjusted so as to obtain a minimum near the geometric center 25 and a maximum adjacent to the anode 21, with one or more potential maxima (virtual anodes) and minima (virtual cathodes) concentrically enclosed within the cathode 20.

In Column 5

> The essence of the formation of the virtual electrodes is the attainment of particle trapping or confinement and high density by a forced charge separation in spherical geometry. Formation of the virtual electrodes obviously consumes power, and the bi-polar charges are the instruments used in the electrode formation. The more efficiently these instruments are used,

> the less power is consumed in forming and maintaining the virtual electrodes. This invention is directly concerned with these efficiencies.

In Column 12 and 13

> Also, such injection is accompanied by the continuous scavenging of neutral gas which is thereby prevented from entering the anode. This reduces associated loss processes inside the anode and cathode cavities which otherwise would occur by reason of collisions between the ejected ions and the neutral molecules. By maintaining background neutral gas to a minimum in the anodic and cathodic cavities and injecting the fuel ions in distributed form at the anode surface, greater efficiencies are obtained in the operation of the fusor in obtaining fusion reactions.

These excerpts are only a few of the instances where Hirsch explains that the primary goal of his invention (and Farnsworth's invention) is to use space-charge electric potentials to confine ions and electrons in a low background-gas pressure environment by focusing and confining these electrons an ions within the cathode region. Hirsch is quite clear on the point that high background gas pressure is detrimental to ion confinement, leading to inefficient operation in his invention, and that ion-ion fusion is the dominant neutron-producing reaction. The present HPHRGD innovation seeks to prevent the formation of, or absorb, as many electrons as is necessary to ensure that space charge potential structures <u>do not</u> form because these structures result in lower operating pressures for sustaining the discharge, decreasing the target density. The HPHRGD does not generate fusion neutrons by confining ions; it generates fusion neutrons by ion and fast-neutral collisions with the background gas target. Because of this, high gas pressures are desired to (1) create fast-neutral particles and (2) provide a high target density with which the fast-neutral particles and ions can fuse. In the case of the HPHRGD, space charge potentials would prevent the desired high operating pressure.

Another difference between Hirsch's neutron generator and the HPHRGD lies in the function of the electron management systems. Hirsch's electron management system sought to improve the efficiency of forming and maintaining the virtual electrode trapping and confinement system. This difference is highlighted by the different bias voltages applied to

the electron management system electrodes, as can be seen by comparing Hirsch's electric potential diagrams with those of the present innovation. In Hirsch's device, the potential within the cathode is very different from the vacuum potential (it is not flat) because the electron management system confines electrons within the cathode region, for acceleration and focusing at the geometric center of the device, with minimal losses. Miley's system disregards an active electron management system altogether and operates in a high-loss (inefficient) mode.

In the HPHRGD, the electron management system is designed to absorb/remove electrons, thereby eliminating space-charge potential formation. It is also noteworthy that there are no internal material structures within the cathode assemblies of Hirsch/Miley that might intercept particles (ion, fast neutrals and electrons). In the present innovation, the baffle electrodes (see Claim 76) extend across the interior of the cathode and are deliberately designed to intercept some particles, particularly electrons, while not producing, and definitely not confining, secondary electrons.

These differences are not natural extensions or simple modifications of the innovations of Hirsch and Miley. In their systems, electron absorption and fast-neutral formation are losses because they destroy ion confinement, which prevents ion density build-up and ion-ion fusion. In the present innovation, no confinement is desired because the energy required to sustain a confinement mechanism, i.e. high electron space charge, is too great for a compact neutron generator. This is not to say that confinement will always be less efficient. At some point, the benefits of confinement provide more efficient operation; however, this point of operation generally lies with much higher input powers than those considered to be of interest with the present innovation. The input power required to make a confinement system more efficient than the present innovation is orders of magnitude greater than the desired input power levels for a neutron source.

A designer trying to achieve a fusion neutron source using a confinement technique, such as IEC, would not want to have their neutron source operate in a gas-target mode of operation because that destroys confinement. In fact, the designer cannot operate IEC with as high a pressure as the HPHRGD neutron source. If the background gas pressure in a Hirsch/Miley type of neutron source were increased to those of the HPHRGD of similar size, the Hirsch/Miley type devices would never be able to achieve high-voltage operation, without

greatly increased current (power) because the conductivity of the gas/plasma would be too high (more background gas + space charge potentials = high ionization rate = high conductivity). Such a device would be completely electron dominated and limited to voltages on the order of a few kilovolts or less, which is hardly enough accelerate ions to fusion energies. The high-pressure high-resistance neutron generator cannot be achieved in a Miley or Hirsch type of fusion device.

At this point, it should be abundantly clear that the HPHRGD neutron source of Claim 68 is fundamentally different from the neutron sources proposed by Hirsch and Miley, despite any superficial similarities in their external physical appearance or shapes. Hence, because independent Claim 68 is patentable, dependent Claims 69, 71-73 and 76 are also patentable. It is thus respectfully requested that the claims be favorably reconsidered and the rejections thereof on the prior art be withdrawn.

In re Appln. of Jurczyk et al
Application No. 10/058,561

Conclusion

The application is considered in good and proper form for allowance, and the Examiner is respectfully requested to pass this application to issue. If, in the opinion of the Examiner, a telephone conference would expedite the prosecution of the subject application, the Examiner is invited to call the undersigned attorney.

Respectfully submitted,

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